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**OPTOMETRIC MANAGEMENT OF VIDEO DISPLAY
TERMINAL RELATED VISION PROBLEMS**

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I. INTRODUCTION

Advance in technology and communication has left no segment of the world untouched. The impact of digital technologies has been accelerated and amplified over the last years by the burst in the depth of data available. Consequently, business models have changed, leaving an essential mark on the modern community. With the rise of modern technology and price drop on the computer market, more and more people all around the world have become able to afford a new digital device to communicate, access the news, spend their free time playing games and watching movies. Therefore, the eyes have suffered a crucial change, spending more time being used to seeing small things at a shorter distance than any time in the history. As a result of a huge modification of our work surroundings, the emphasis has shifted from distance to two dimensional near vision tasks such as reading, writing and computer viewing. Because near work consists of sufficient vergence and accommodative abilities, it can cause ocular discomfort to the people who lack those. After only a few minutes, the eyes can become fatigued and consequently further visual performance can be reduced (5). In addition to reduced visual performance, physical and mental well-being could be influenced, which often negatively impacts productivity, concentration on the task and can also increase the number of errors.

Since the number of office workers and also members of the younger generation - in whom was found the correlation between visual discomfort and over use of modern digital technology - has grown, the American Optometric Organisation has compiled a list of the most typical symptoms and named the visual disturbance of today's community, the Computer Vision Syndrome (14). In order to help the patients, many brochures have been published to provide the necessary information to all eye care professionals. However, due to the uncontrollable growth and expansion of the digital device market, the Computer Vision Syndrome could become one of the most threatening conditions to the visual system, with possible long-term impact on the entire population.

II. NEAR VISION

2.1 VISUAL SKILLS

There are many components of the visual system that must effectively collaborate that the best visual performance is achieved, particularly binocular vision and accommodation, which, along with papillary constriction, constitute the near triad.

Binocular vision is the highest level of vision and characterises the human ability to perceive the image of the surroundings. It is a huge asset in case of the normal alignment of the two eyes, but can quickly become an obstacle even if minimal misalignment is not properly observed and treated.

Binocular vision is a state of simultaneous vision made possible by correct usage and coordination of both eyes. In this case, the two separate images created by each eye can be perceived as a single three-dimensional (cyclopean) image (1). In clinical practice, three levels of binocular vision can be observed, as given by Worth's classification (1):

1. Simultaneous vision – simultaneous vision is the ability to perceive two images by both eyes at the same time (binocular vision). Its presence excludes the phenomenon of suppression.
2. Fusion – fusion is the ability of the brain to interpret the two different images and to provide a single image as an output. It is characterised by two separate processes that happen sequentially. Motor fusion is the first step of the fusion that allows maintaining alignment of the visual axes on an object, as either the object or the body changes position. The second step is the interpretation of the two inputs of visual information and the combination into a single image. This process is initiated by the signals sent from corresponding points of each retina.
3. Stereopsis – stereopsis is the ability to perceive a single three dimensional image of the observed object. Since the eyes are positioned along the horizontal axis, retinal images are not the same. The differences are integrated into a single image; consequently it is possible to recognise the shape and the depth of the object.

Binocular vision is classified as normal when it is bifoveal and when there is no manifest eye deviation. When the images of the fixated object are projected on the fovea of one eye and on an extrafoveal area in the other and a small strabismus is manifested, binocular vision is diagnosed as anomalous.

Accommodation is a process in which the ocular lens modifies its shape in order to change the focus length in relation to vergence of the light entering the eye. Thanks to the ability of changing lens shape, it is possible to maintain a clear image or focus on the object as the distance varies. Ciliary muscle held by the zonular fibres is also included in this process, which by contraction and relaxation of the fibres changes shape of the lens. This ability is lost around the age of 40, when the rigidity of the nucleus of the lens reduces accommodation because the sclerotic nucleus bulges anteriorly and changes its anterior curvature (2). Many scientists have tried to explain the mechanism of accommodation in theory; however, the Helmholtz theory is the one most widely accepted. Helmholtz claimed that most of the accommodative change in lens shape occurs at the central anterior lens surface, while the posterior surface curvature changes minimally (3).

Accommodation is controlled by the parasympathetic fibres of the fifth cranial nerve, also known as the nasociliary nerve of the trigeminal, that innervate the ciliary muscle. When the M3 muscarinic receptors are activated, the contraction of the ciliary muscle is triggered by acetylcholine receptors, formed by G-protein complexes, and thus the reduction of the ciliary muscle ring diameter is induced. This process allows the relaxation of zonular fibres, the consequent change of the lens shape and the improvement of near vision (4).

The amplitude of accommodation is the amount of change of refractive power of the eye that is produced by the accommodation (2). Young people normally have the AA of 12-16 D, whereas the AA decreases to 4-8 D with individuals aged around 40 (2). After the age of 40 the AA starts to decrease even more, also below 2 D. The condition of lens hardening with age and causing the loss of accommodation is called presbyopia.

Apart of accommodation and binocular vision, there are some other visual skills included when performing a near visual task. Normal visual perception requires also smooth functioning of the ocular motor systems, which are controlled by six

extraocular muscles. However, in order to carry out a near task as efficiently as possible, normal multiple sequential eye movements, called saccades, must be executed. Saccades are rapid, simultaneous ocular movements that change the point of fixation in order to clearly see the object located more peripherally. Even though saccades are elicited voluntarily, they occur reflexively when working with the computer or other digital devices. Normally, the initiation of a saccade begins with about a 200-millisecond delay, due to the time needed for visual stimulus to be registered by the primary visual cortex. Extraocular muscles, which move the eye in the correct direction of the visual target, are activated during the delay (105).

2.2 VERGENCE AND ACCOMMODATIVE DYSFUNCTION

Vergence and accommodative dysfunctions are not the same visual anomalies and must be approached differently. The smallest dysfunction can harm the worker's or child's productivity and can negatively affect their working performance. People who are likely to be affected by one of those anomalies are usually those who tend to use computer extensively and perform a considerable amount of near work. The optometrist's most important job, when examining the patient with vergence and accommodative dysfunctions, is to carefully scrutinize the symptoms such as blurred vision, headache, eye fatigue, diplopia and concentration loss and to suggest the correct treatment (5).

Even though there have been many attempts to classify vision problems, not every patient fits into a specific diagnostic category. Most people who come to visit an eye care professionals tend to have more defects and various symptoms. Since the accommodative and vergence systems are controlled by an interactive negative feedback loop, the patient with an accommodative problem may have another secondary vergence problem, while the one with a vergence problem may have a secondary accommodative problem (6). For a better possibility of making a correct diagnosis and determining the correct plan of treatment for the patient, the American Optometric Association has created guidelines and proposed a classification of vergence and accommodative dysfunction.

The Duke-Elder classification is used to classify accommodative dysfunction (7).

- Accommodative Insufficiency: it occurs when the amplitude of accommodation is lower than expected considering the patient's age. Other important signs during an exam are slow response to minus lens (monocular accommodation facility) and uncorrected or latent hypermetropia.
- Ill-Sustained Accommodation: the amplitude of accommodation is normal, but fatigue increases with repeating accommodative stimulation (7, 8).
- Accommodative Infacility: also called accommodative inertia. It is a condition when the accommodative system is slow in making a change, or when a considerable lag is found between the stimulus to accommodation and the response (8).
- Paralysis of Accommodation: a rare condition in which the accommodative system does not respond to any stimulus. Normally the condition is obtained by the usage of cycloplegic drugs or by trauma, eye disease and poisoning (8).
- Spasm of Accommodation: a rare condition connected to a prolonged ciliary muscle contraction, most commonly causing pseudomyopia (9).

Vergence anomalies, or vergence dysfunction, are binocular vision disorders which result in an inability to maintain comfortable simultaneous bifoveal alignment or are simply a result of a fusion failure (5). The system originally developed by Duane for the application to strabismus is one of the most commonly used for the classification of vergence dysfunction (10).

- Convergence Insufficiency: a condition characterized by a receded near point of convergence, near exophoria, reduced positive fusional convergence, deficiencies in negative relative accommodation and low AC/A ratio (10).
- Convergence Excess: the patient with convergence excess has a near esophoric deviation, mostly indicated by a high accommodative convergence/accommodation (AC/A) ratio (11).
- Basic Exophoria: notable exophoric deviation of a similar magnitude both near and at a distance (11).

- Basic Esophoria: characterized by high near and distance esophoria and a normal AC/A ratio (10).
- Divergence Insufficiency: higher esophoric deviation at a distance than at near, a low AC/A ratio and low fusional divergence amplitudes at a distance (12).
- Divergence Excess: it is clinically described as a high exophoric deviation at a distance and far lower than the near deviation (13).

III. COMPUTER VISION SYNDROME

3.1 HISTORY OF COMPUTER

The amount of time spent behind digital screens has grown dramatically in the last decade. Even though the computer was not invented for entertainment, it has changed the modern society's lifestyle. The history of computers has its beginnings in the 19th century, when the Analytical Engine was first introduced and created. Just before the Second World War J.V. Atanasoff, Clifford Belly and later Alan Turning actually created machines that were capable of storing information on their main drives. However, it was in 1976 that Steve Jobs and Steve Wozniak entered on the market with a brand new style of personal computer that made an enormous impression on even the middle class, who had not been able to afford it before (15). Since then, the world has been rapidly digitized by an exponential growth of digital device users. Because of a huge burst of computers in the last decades, it is difficult to provide an exact number of computer users throughout the world. Therefore, different associations have established some basic terms and collected data from all around the world in order to learn how many individuals have access to the internet, which has been significant in calculating the prevalence of CVS.

As of 2018, more than fifty five percent of the world's population have access to the internet. The number reaches even higher values when speaking about the European population; according to Internet World Stats, more than eighty five per cent of people living in Europe have internet access (16). Italy is one of the countries with the biggest population having an internet access, with 92.5 % of people being internet users.

Additionally, because of the easy way of using digital devices, in-between computers, cell phones, tablets and other digital screens, some people spend an average of eight to ten hours a day looking at screens. The overuse of those increases the eye discomfort and causes an additional strain on eyes, leading to some of the most common symptoms.

Since the establishment of the World Wide Web, the internet has provided many services that are accessible to all generations, from the youngest to the oldest. Activities such as e-mail communication and finding information about different goods are the most popular among people aged from 16 to 74 years (17). A similar number of users, about 70 % of them, are interested in reading online news and magazines, without there being a significant difference among age groups.

Nevertheless, a bigger contrast between young and older generation is observed when it comes to other uses of the internet, such as the use of social networks and other entertainment sites and video call communication. In 2016, 88 % of 16 to 24 year olds were using at least one of the most common social networks compared to 38 % of 55 to 74 year olds. Similar patterns have been observed with activities such as making video calls through internet-based applications: 54 % of users aged from 16 to 24 compared to 30 % of users aged from 54 to 77 (17).

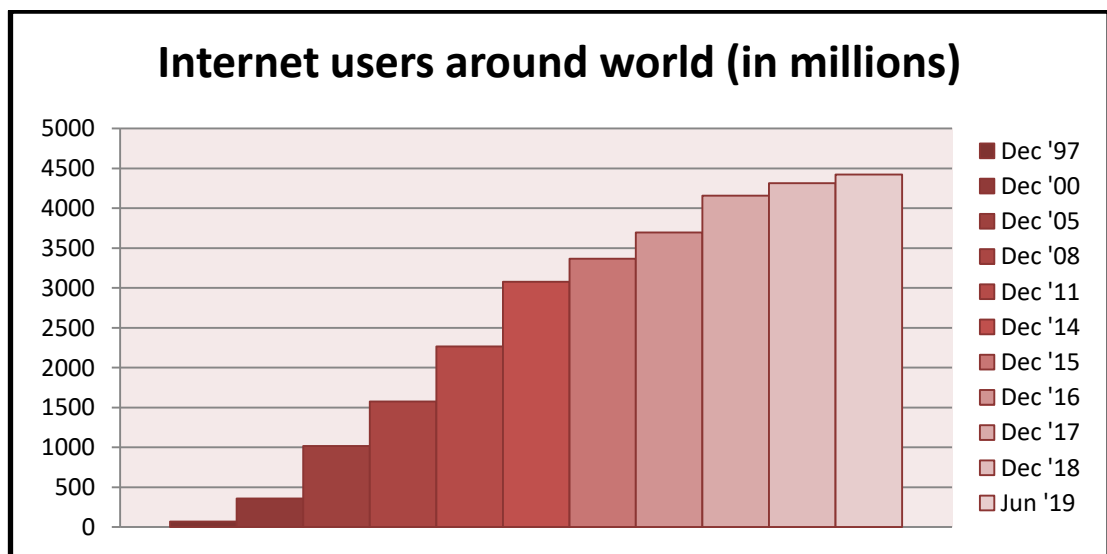


Image 1: Growth in number of internet users all around the world from 1997 to 2019, according to the Internet World Stats (16).

3.2 DEFINITION

Because of the increased use of computers, the American Optometric Association has gathered the most common eye and vision problems related to near work and

experienced during computer use and established the term to describe them as the Computer Vision Syndrome (CVS), also known as Digital Eye Strain (DES) (14). Many patients complain about their vision, especially if their work is directly connected with performing near tasks, which are mainly considered as reading on computer displays. The symptoms, such as eyestrain, headaches, blurred vision, dry eyes and neck or shoulder pain, are often associated with poor and improper working conditions and are only temporary and often decline with a reduced amount of time spent in front of video display terminals (14).

Computer Vision Syndrome does not appear only as an occupational disorder in workers (such as office workers, film directors, journalists, researchers, et cetera) but also in the younger population, as the educational reading assessment is being increasingly digitized. The prevalence among students is the highest in countries with a well-developed school system, where high expectations about the educational performance are present.

It is necessary to understand what causes Computer Vision Syndrome. Since many symptoms can be easily mistaken for a different condition, it is of primary importance to establish what the original cause of the patient's visual discomfort is. This is why the CVS has been under observation and finally given a definition in many countries around the world. A Video Display Terminal, a VDT, has been consequently defined as a system composed of a display screen, a keyboard and a central processing unit. Furthermore, it has been determined that a display screen being the output of the VDT shows what the computer is processing, as well as the central processing unit being the brain of the computer. The most common VDTs of today's society are a personal computer and a laptop. Apart from VDTs, there are also some other digital devices that can cause CVS, such as smart phones, tablets and e-readers.

3.3 RISK FACTORS FOR CVS

The impact of modern technology has caused an evident change in the behaviour at the work place. Since the textual characters differ in several aspects from the hard-copy characters, a different approach is needed when resolving CVS.

In the last years, many well-controlled studies have shown that the prevalence of CVS symptoms was higher among computer users who worked for more than six hours a day. In addition, many authors claimed that the duration of computer use was directly connected with the ocular and musculoskeletal symptoms, and that prolonged use of digital screens contributed to long-term complaints, also once the work has been completed. Because of the exponential growth in patients diagnosed with CVS, researchers and eye care professionals have started to analyze the problem thoroughly and have been looking into the risks that cause CVS. Apart from the time spent behind digital screens, contact lens wear is another likely cause for the aforementioned symptoms. A higher prevalence of symptoms was noted in contact lens wearers, who are also four times more likely to develop complications connected to dry eye (18). The position of the VDT has also been mentioned in various studies. The distance, being shorter than normal, overloads the eyes, which have to accommodate more. This results in headaches and eye fatigue induced by the overworking of the ciliary muscles.

Other significant risks include the height and the inclination of a digital screen, and not taking breaks while using the computer. It has been reported that more symptoms were induced due to an inappropriate monitor position, or more precisely the height. The risk was higher when the computer workers observed the monitor at eye level, than when positioned below eye level, averaging about 18 cm lower (19). Moreover, eye inclination plays an important rule, particularly in reducing asthenopia; when the screen is below the eye level, the visual discomfort is more likely to be avoided.

Ultimately, there has been a lot of discussion whether the blue light emitted from digital screens may be a factor that causes CVS, but there is no published evidence that supports this claim. Blue light emitted from computer monitors and other digital devices is a part of the visible spectrum of electromagnetic radiation. It is included in the spectrum from 380nm to 500nm together with violet, indigo and blue-green lights (20).

3.4 DIGITAL SCREEN CHARACTERISTICS

It is widely believed that near work at the computer along with prolonged use leads to an unpleasant state of the patient's eyes. In addition to those main factors, there are many other that are associated with Computer Vision Syndrome. In the last decades, there has been a lot of discussion concerning digital screens and it has been found that the human eyes behave differently when viewing a digital screen in comparison with a printed page. Solid black letters on a white background with well defined edges induce a perfect visual response, while looking at digital characters does not. This happens because of computer characters composed of pixels. A pixel is the smallest element of a digital image or graphic that can be displayed on a video display system (21) which is bright in the center, but the amount of brightness decreases when moving towards its outer edge (22). The characters on a digital screen have a Gaussian or bell-shaped-curve energy distribution as measured by the light meter (23). The result of this structure is a loss in higher spatial frequency information content that is required to produce a sharp-edged visual stimulus, which can be produced when observing a printed text (24); the elimination of high spatial frequency information is associated with a reduction in accommodative accuracy (25). Furthermore, a direct link has been found between image contrast and accommodation; both the bell-shaped-curve form and the reduced contrast of the digital character produce a shift in focus towards the resting point of accommodation (26). That being said, a pixel generated image could be understood as an unclear element of digital text that drives accommodation in the same way, as would an empty, plain field.

3.5 PATHOPHYSIOLOGY OF CVS

Due to well-defined edges with good background and contrast, the human eye focusing mechanism responds better to the printed text, rather than to electronically generated characters. In addition, work behind digital screens is demanding and consists of frequent saccadic eye movements, accommodation and vergence (alignment demands); all of those functions involve continuous muscular activity (14).

Moreover, digital characters being made of pixels, the human eye cannot maintain focus easily; in the attempt to focus on the plane of the digital screen, the eye fails to maintain its focus and therefore relaxes to focus behind the screen (27). This point is referred to as the Resting Point of Accommodation or the Dark Focus. The continuous change in relaxation from the Resting Point of Accommodation to straining to refocus on the screen leads to eyestrain and fatigue (28). Since the lens focuses slightly too far when working at a near distance, different degrees of tension are put on the ciliary muscle, so the refractive power is increased. In addition, when the eye is focused at near distance, the refractive power of the crystalline lens varies; this process is called accommodative micro-fluctuations (39). In the case of a patient diagnosed with CVS, a distant visual target does not put a high amount of tension on the ciliary muscle.

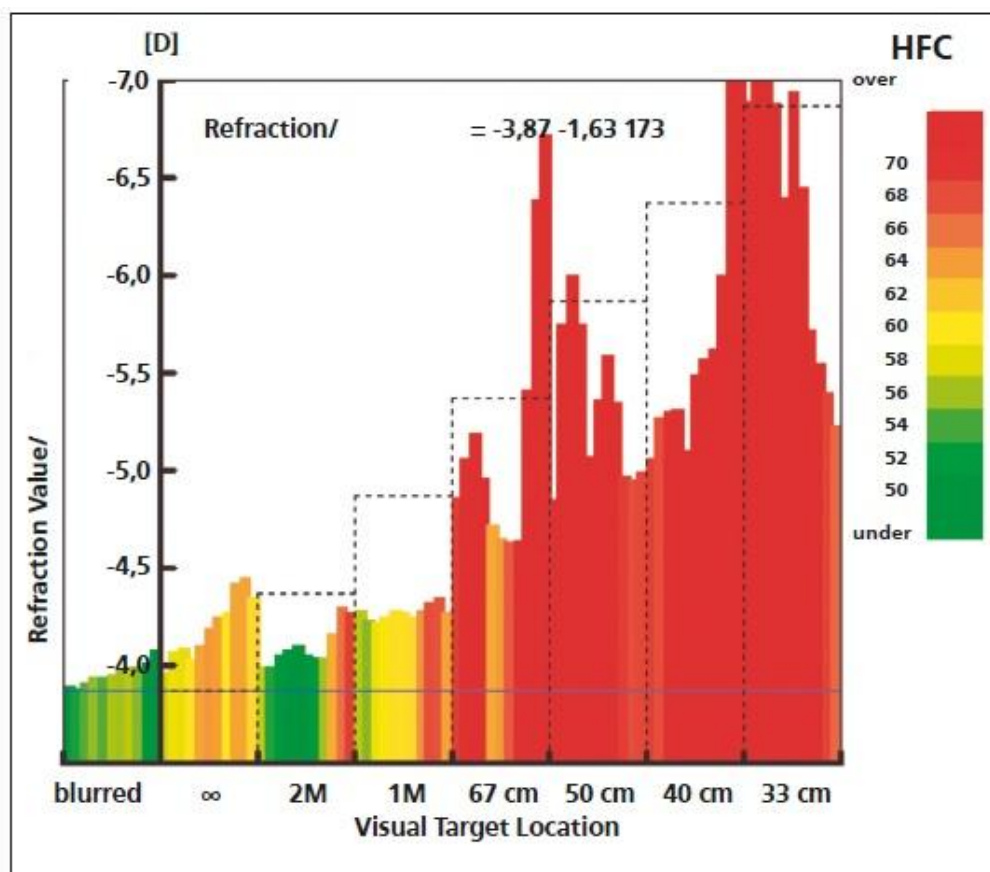


Image 2: An Fk-map is an objective accommodation functional analysis of lens tremors. Red coloured bars represent high frequency component in micro-fluctuations. In the case of CVS, high tension is put on ciliary muscle when working at a short distance (39).

However, when working at a near distance, eye pain and headaches are induced, by a spasm-like condition caused by strong tension in the ciliary muscle (39).

In the last decade, there has also been a lot of debate concerning the effects of three dimensional games, movies and televisions, which together constitute a computer-based online community environment, also known as the virtual world. An increase in patients with similar symptoms to those of the CVS, such as eyestrain, blurred vision and headaches, has triggered different opinions about the 3D devices. It has been suggested that the artificial 3D technology affects vision and causes a conflict between the convergence and accommodation systems; the patients, in case of 3D use, must focus on one point from which the light is emitted and verge on another point where the 3D objects appear in the space (29). This phenomenon could lead to the collapse of the natural linkage between vergence and accommodation, so the patient would have to force more in order to avoid blur and diplopia.

Blue light is considered to play an important role in vision connected problems, causing damage to retina, cornea and lens. Other than ocular induced injuries, it can also cause the loss of contrast in the retinal image and also in the physiological cycle (30, 31).

It has been widely discussed whether the blue light can cause photochemical damage leading to the death by apoptosis of retinal pigment epithelium and then photoreceptors, by inducing the formation of toxic reactive oxygen species. (32) To support previous speculations, researchers from Paris Institute of Vision and Essilor developed improved experimental techniques and, by exposing the RPE cells to extremely narrow spectral bands (from 390 nm to 520 nm in 10 nm increments), found that the greatest damage of RPE cells resulted from sub-bands within the blue-violet spectrum between 415 nm and 455 nm (20). Despite these findings which are more of a speculation than significant evidence, no clinical study to this date has demonstrated that the prolonged use and overexposure to digital screens is directly connected to early macular degeneration. Nevertheless, blue light emissions not only influence vision, but also induce problems that are noticed later during a comprehensive eye exam (33).

The cornea is the first ocular structure that is passed by the light. Studies have shown that over-exposure to blue light decreases the survival rate of corneal epithelial cells, reduces the support of the microvilli on the epithelial layer and has an inhibitory effect on corneal stromal cell activity. Nevertheless, the potential long term effects on the cornea need to be further studied (34).

Smaller smart devices, such as mobile phones, e-readers and tablets have become indispensable before bed. It has been speculated that habitual exposure to blue light before sleep, significantly reduces the production of melatonin, a natural hormone produced by the pineal gland, which is released into the blood normally in the evening. However, when the exposure is excessive, particularly at night when melatonin production peaks, it can stimulate the brain and inhibit melatonin secretion, and can therefore directly affect sleep quality (35). In addition, many studies have shown that the reduction of the body's androgen cells could be the consequence of the lack of sleep. Some research has shown that the lower amount of androgen can lead to the eyelid's gland dysfunction and can induce the feeling of dry eyes because of the reduced lacrimal lipid layer's secretion (34, 36).

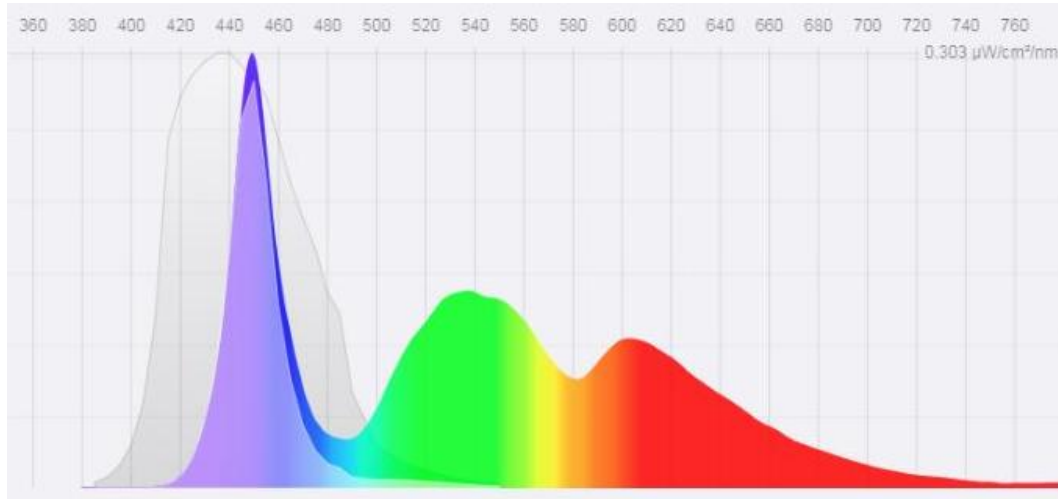


Image 3: The graph reveals that the peak wavelength tends towards lower wavelengths (blue peak $0,303 \mu\text{W}/\text{cm}^2$ at 450nm) (40).

Digital devices have a huge impact also on children and young adults. There have been continual discussions about how modern technology interacts with human biology. The prevalence of myopia has increased extremely and it is estimated that nearly half of the world's population will be myopic by 2050 (37). In some

parts of Asia, especially in the south-east, the rate of myopic teenagers already reaches 80 % and even more. The epidemic growth of myopic teenagers in Asia has been correlated with the increased amount of near work in school and decreased amount of time spent outside. With digitalization and more time spent behind digital screens, particularly behind smaller devices such as smart tablets and phones, those numbers are very likely to spread all over the world.

The implications of the myopia epidemic are not just more people needing glasses, but also increase in pathological conditions. High myopia ($> 6D$), an indicator of possible pathological complications, is predicted to affect more than a billion people by 2050 (37). Since the abnormal ocular changes in case of high myopia, such as retinal detachment, glaucoma, cataract and posterior vitreous detachment could threaten the patient's vision, more people will be at risk of losing their vision in the future.

The recognition of prolonged near work habits and the continuous use of digital devices at abnormal distances as a possible risk for myopic progression may lead to significant health complications. Outdoor activity, taking breaks and longer reading distances as a part of prevention could decrease the patient's discomfort and especially result in the late-onset form of myopia (38).

IV. IMPACT OF DIGITAL DISPLAYS ON VISUAL PERFORMANCE

4.1 SYMPTOMS

One of the most common sentences heard in most eye care professionals' exam rooms is that the human visual system is biologically designed for distance vision. However, in such a rapidly modernizing world, particularly in developed and developing countries, where digital devices have changed the way of living, the increase in visual disorders is linked to the proliferation of screens and the time spent looking at them. Since near vision is only a mechanism of the accommodation reflex that helps to quickly identify objects at small distances, prolonged staring at close digital screens causes different visual symptoms.

Much research has been conducted in the third millennium to differentiate between the Computer Vision Syndrome and other visual disorders.

According to the American Optometric Association, the most common symptoms associated to CVS are (14):

- Eyestrain.
- Headache.
- Blurred vision.
- Dry eyes.
- Neck and shoulder pain.

Several distinctions of symptoms induced by CVS have already been mentioned. External symptoms, such as irritation, dryness, burning feeling and tearing are often linked to dry eye, whilst internal symptoms, such as strain and headache, were linked to accommodation and binocular dysfunctions. In addition, there is a clear division of symptoms into two categories: signs associated with accommodation (blurred near vision, blurred distance vision after prolonged near work, difficulty to rapidly change the focus from near to distance or from distance to near) and those associated with dry eye (dryness, irritation, tired eyes, sensitivity to bright light, discomfort) (41).

Furthermore, musculoskeletal symptoms are also a very common problem of prolonged computer use and are indirectly correlated with visual problems. Upper body pain is connected to inappropriate location of the display, improper working station set up and finally to visual dysfunctions. In 1958, Dr. Darrell Boyd Harmon noted that vision functioned in gathering and using information, in determining spatial frames of reference and in guiding movement. Many of the problems that were believed non-visual turned out to be related to visual tasks. For example, Harmon noticed that particular deviations of head's orientation could be correlated with refractive error; astigmatic children tend to tilt the head laterally, myopic children backward, hyperopic children forward and children with anisometropia tend to rotate the head in the horizontal plane. The abnormal postural behaviour for hours puts stress on the muscles and discs of the upper body and causes neck, back and shoulder pain (42). However, the incidence of musculoskeletal complaints linked to the improper computer work station positioning has increased. In addition to the worker's discomfort, a correlation to the reduced productivity has been found to have an enormous financial impact on the company's economics (43, 44).

The prevalence of CVS has received great attention from scientific analysts in the last years. The evaluation of the growing impact of CVS on computer users has met with various challenges, due to the uneven usage condition and different subjective perception of the problem. Through a wide range of methodologies researchers have succeeded in identifying sufferers and in approaching CVS correctly. Recent data indicates that Computer Vision Syndrome is a very common problem internationally. Despite its significant growth, it can be easily resolved if approached with proper methods.

The prevalence of CVS has been under observation for the last two decades. The greatest challenge, due to the wide variation of usage conditions and substantial changes in these over time, is the to actually determine the number of people suffering from CVS. One of the key reports, published in 2016, which included survey responses from over 10,000 US citizens, identified an overall symptom prevalence of 65 % (45). Similar numbers were noted also in other recent studies, ranging from 67.4 % to 89.0 % (46, 47).

Considering a few of the most accurate studies, the symptoms stated in the AOA's definition of CVS correspond to the symptoms listed in those studies. The symptoms are divided into internal symptoms, external ocular symptoms, visual symptoms and musculoskeletal symptoms (48).

The internal (or asthenopic) group of symptoms mostly includes eyestrain, headache and tired and sore eyes. 53 % to 74 % of respondents reported eyestrain and headache as the main disturbance (47, 41). The second most irritating symptom is tired and sore eyes, the percentage of patients reaching as high as 40 % (41). Internal symptoms are the symptoms for which most of the patients seek medical advice. They usually occur in the middle or at the end of the day, whereas in the morning the discomfort disappears. Headaches are normally located in frontal part or are experienced as being one-sided (28).

External ocular symptoms are divided into dry eyes, irritated and itchy eyes, redness, burning sensation. 31.1 % to 59.9 % of users reported dry eye and up to almost a half of participants stated that their eyes were itchy (46, 47). External ocular symptoms are more likely to increase in the group of contact lens users with six hours of work behind digital screens, with the prevalence of 50 % to 60 %, respectively (49, 50). Shadid et al. have compared tear film break-up time (TBUT) between VDT users and not and found that 42 % (N=150) of participants had the TBUT under ten seconds (the American Optometry Association considers normal break-up time from 15-20 s and lists TBUT as abnormal when under ten seconds) (51, 52).

There can appear visual symptoms such as blurred near and distance vision, slowness of focus change from one distance to another, double vision and light sensitivity. Blurred vision among computer users could be a result of various factors, such as refractive error, improper lens prescription, poor quality monitor and reflected glare from the screen. Binocular dysfunction can also lead to the visual symptoms; looking at a close digital screen stimulates the convergence of the eyes. If the eyes do not converge properly, which can happen in case of convergence insufficiency, the patient might be distracted by intermittent double vision. Diplopia in this case is mostly transient as it disappears after resting the eyes by looking away from the screen. Rarely, mostly in children, convergence

excess causes difficulties such as the lack of concentration on near tasks and in case of manifest deviation also ambliopia. Moreover, accommodative dysfunctions such as accommodative insufficiency, accommodative excess and accommodative infacility can lead to undesirable visual symptoms (5).

Musculoskeletal symptoms are mostly represented by neck pain, shoulder pain and back pain. The prevalence is between 21.9 % and 54.0 % (53, 47) Musculoskeletal problems are normally a consequence either of constant change of posture in an attempt to see the digital screen better or the result of a constantly improper position of the body, due to uncorrected refractive error or the inappropriate workstation design.

Other Computer Vision Syndrome symptoms that have been reported by the affected users are tiredness at work and home, lack of concentration, nervousness and irritation. All those symptoms could negatively affect workers productivity and also the quality of their private lives (54).

Tab. I: Selected international researches regarding Computer Vision Syndrome and its main symptoms, in descendent chronological order.

Author	Study design	Sample	Age of participants	Amount of VDT work	Results
Shahid E. et al. 2019 (52) Asia	Cross-sectional	150 diagnosed CVS patients	Not indicated	5.96 ± 2.82 hrs/day	- Decreased tear film break up time was the cause of ocular discomfort in many patients (less than 10 s in 42 %)
Sá E. C., Martinez M., Fischer F. 2018 (54) Brazil	Cross-sectional	303 computer operators	Not indicated	Not indicated	- Participants indicated tiredness at work (47.9 %), weight in the eye at work (38.3 %), tiredness at home (36.3 %). - Correlation between eye symptoms and interruptions at work (3.7 %), overtime work (3.6 %) and increased demand (3.6 %).
Ranasinghe P. et al. 2016 (46) Sri Lanka	Questionnaire study	2210 computer office workers	Mean age 30.8 ± 8.1 years	At least 2 hrs/day	- Headache (45.7 %), dry eye (31.1 %) and pain around the eyes (28.7 %) were most common - Prevalence of 67.4 %
Tauste A., Ronda E., Molina M. J., Segui M. 2016 (49)	Cross-sectional	426 office workers	Mean age 47.3 years ± 8.9 years	3-6 hrs/day	- Contact lens wearers are more likely to suffer from CVS than non-lens wearers
D'Erceville S. 2015 (47) International	Questionnaire study	4000 random people	18-65 years	Not indicated	- 89 % of participants felt discomfort or pain in their eyes. - Eyestrain (74 %), itchy eyes (50 %), dry eyes (46 %) and musculoskeletal problems (54 %)

Tab. I: Selected international researches regarding Computer Vision Syndrome and its main symptoms, in descendent chronological order.

Author	Study design	Sample	Age of participants	Amount of VDT work	Results
Reddy et al. 2013 (53) Malaysia	Cross-sectional	795 university students	18-25 years	< 2 hrs (59 %) > 2 hrs (41 %)	- Headache, eyestrain, blurred vision and dry eye were the most significant in 59.9 % of participants, followed by musculoskeletal problems (21.9 %).
Agarwal et al. 2013 (55) India	Cross-sectional	150 computer operators	Not indicated	< 2 hrs 2-6 hrs > 6 hrs	- The most common symptoms in the group > 6 hrs were eyestrain (53.0 %), itching (47.6 %) and burning (66.7 %). - Similar percentage of users who worked at the computer < 6 hrs, notable increase of symptoms in the group > 6 hrs
Portello et al. 2012 (41)	Questionnaire study	520 office workers	The mean age 39.3 years	Media of 6 hrs/day	- Nearly 40 % of workers indicated tired eyes, other symptoms were dry eyes, eye strain, eye irritation, burning eyes
Shima et al. 1993 (56) Japan	Questionnaire study	- 45 non VDT users - 204 VDT users	Not indicated	- 1 hrs/day - more than 1 hrs/day	- Important difference between VDT users and not - Eye pain (20.0 % among non users, 46.2 % - 67.8 % among VDT users), blurred vision (40.0 % among non users, 50.4 % - 65.5 % among VDT users).

4.2 MEASURING COMPUTER VISION SYNDROME

In the last decades, eye vision care has evolved rapidly. The variety of instruments has offered different ways to identify the patient's condition, including Computer Vision Syndrome. There are a huge number of evaluations, subjective and objective, that can be used to identify CVS.

Subjective methods are the easiest for the practitioner and do not demand many instruments. A 10-item questionnaire created by Hayes et al (41) has been used in several studies; to the level of ocular discomfort experienced from the most common symptoms and gives a total symptom score. Other scales that have been created to subjectively identify CVS are the Rasch-based Computer Vision Scale (58), the self administrated Computer Vision Syndrome Questionnaire (based on indication of frequency and intensity of sixteen symptoms, allowing a single symptom severity score) and the six-item Visual Fatigue Scale (49). Subjective questionnaires with verified validity and reliability have become important in every practitioner's office and have become useful by providing additional validation for objective measurements of CVS.

Objective evaluation is as important as the subjective one, although the precise physiological basis remains unclear. Accommodation parameters have received a huge amount of attention given the nature of many symptoms, while other tests, such as critical flicker-fusion frequency and blinking characteristics, have been used by eye care professionals (58).

Critical flicker-fusion frequency (CFF) is the frequency at which a flickering light becomes equivalent to a steady, non-flickering light. It has been suggested that CFF can reflect the basic temporal function of the visual system even though the negative changes in CFF following prolonged computer use has not established a correlation between the worsening of CFF and increased symptoms according to all research (59, 60). However, CFF remains a good measure of visual performance.

Blinking is a bodily function that maintains a normal ocular surface. Every complete blink initiates a cycle of secretion, dispersal, evaporation and drainage of tears (61). There are a number of factors that can affect blinking rate and alter ocular surface. The normal rate ranges from 8 to 21 blinks per minute and can

quickly decrease to an average of 4.5 blinks per minute, when focusing on a specific visual task (62). Reduced blinking rate can rapidly induce dry eye, so the evaluation of the number of blinks before and during computer use is an indispensable test of every eye practitioner during a CVS identification.

For a successful and comfortable work performance, pre-presbyopes must be able to accommodate quickly and fluently and maintain an accurate response (63). A few studies have found that the lag was higher when reading from a digital screen compared with a printed text (64, 65). However, a recent study has reported a similar lag between the most symptomatic and the least symptomatic group, although the task duration (30 minutes) may not represent the heavy usage pattern of patients who are mostly affected by CVS.

The last component of the near triad (along with accommodation and convergence) is pupil response. It has been suggested that the changes in pupillary response could be one of the indicators of visual fatigue, due to harmful effects on the depth of focus (66). It has been also found that the pupil diameter is influenced by the types of tasks; a more demanding near task such as a fast presentation of figures on a digital screen and tracking can induce a significant increase of the pupil diameter, even after 20 minutes of more demanding near work (67). Moreover, there has been noted a reduced pupil diameter and increased pupillary response after a prolonged computer use (67, 68). When the pupillary changes are noted, an open view autorefractor could facilitate the analysis of the post-task pupil recovery (67).

V. COMPUTER VISION SYNDROME MANAGEMENT

It is widely believed that there are numerous factors that contribute to Computer Vision Syndrome, due to the rapid growth in the number of small digital devices all over the world. Furthermore, it has been found that a combination of symptom inducing factors could increase the magnitude of symptoms (69). Eye care practitioners' rule in this modern generational problem is to listen, correctly examine and find an appropriate solution to solve the patient's needs. Therapeutic interventions of Computer Vision Syndrome can be divided into the correction of refractive error, management of accommodation and vergence anomalies and dry eye treatment.

A big difference between those who suffer from CVS (65 %) and those who regularly have their annual eye exams and discuss their usage of digital devices (20.5 %) could be an indicator of the lack of knowledge among patients about modern technology and its effects on the human visual system (45). In addition, the top two reasons for not using appropriate eye wear are that users do not think it is necessary or believe it is too expensive (45). In order to avoid the symptoms, education and prevention should also be considered in eye care professionals' offices. The American Optometric Association has published many studies and guides on how to approach patients suffering from CVS. Various policy recommendations have been applied to educate patients, such as the 20/20/20 rule, education about CVS itself, environmental modification at the workplace and the patient's proper self eye care, so it is crucial to develop and distribute this information so as to improve public understanding.

5.1 CORRECTION OF REFRACTIVE AND ACCOMMODATIVE ANOMALIES AND VERGENCE ANOMALIES

The correction of refractive error and presbyopia seems to be the most important intervention in CVS sufferers. Studies have shown that even a low amount of uncorrected astigmatism (0.50 – 1.00 D) could negatively impact the patient's

visual comfort and their working productivity (70). Uncorrected astigmatism represents a big issue among uninformed adults who, rather than seeing an eye care professional, buy off-the-shelf reading glasses and also among contact lens wearers with uncorrected cylindrical errors.

The presence of any refractive or accommodative anomaly, such as accommodative insufficiency or infacility, could affect the patient's visual discomfort. During an examination the following clinical parameters should be assessed (71):

- Best corrected visual acuity.
- Refractive error (including binocular balancing).
- Accommodative error at the appropriate working distance.
- Monocular and binocular amplitude of accommodation.
- Monocular and binocular accommodative facility.
- Negative and positive relative accommodation.

During an eye exam it is extremely important to know the patient's working distance; the variety of working distances, due to the use of different smart devices and computers, can problematically impact the decision concerning the amount of near vision addition. Different working distances are the result of different font sizes; for example smaller fonts on smart phones reduce the standard working distance of 40 cm to 32.2 cm (72). On the other hand, minimum distances of 50 to 65 cm for computer monitors have been recommended, while typical recommended distances for e-readers and tablets users are around 50 cm (73). The purpose of prescribing a plus lens is to decrease the demand on the accommodation system and to reduce the amount of esophoric deviation by manipulating the AC/A ratio. The prescription of the most suitable plus lens consists of the equalization of negative and positive relative accommodation, balancing the levels of the phoria, near point/dynamic retinoscopy findings and finally the patient's subjective response to the plus lens. Although significant, a single vision near glasses with single addition may not be the optimal solution for the whole range of demand levels, meaning that the patient would require multiple prescriptions for different digital devices. So called progressive computer glasses

have been designed in the last decades to optimise the vision in the intermediate and near regions that may reduce CVS symptoms.

Single vision lenses designed for computer work that provide the largest field of view are often more useful than bifocals in symptomatic computer users. Bifocal presbyopic lenses are designed for near work and have the addition plus power positioned in the lower segment of the glasses; consequently, the user is being forced to view the digital screen by tilting the head backwards in order to see it through the bottom segment of their lens. The induced inappropriate postural behaviour stresses various muscle groups and leads to neck, shoulder and back pain (74). In addition to single vision lenses, occupational progressive lenses are also one of the most popular designs of computer glasses. Occupational progressive lenses work in a similar way as the traditional progressive lenses; both are multifocals with the upper segment used for distance vision, the intermediate segment for intermediate vision and the bottom segment used for near reading tasks. However, the difference between these multifocals is essential when working at intermediate distances such as when using the computer. Occupational progressive lenses provide wider corridors than traditional progressive lenses. Nonetheless, the huge advantages in terms of corridor width come at the expense of the reduced top part of the lens (limited field of distance vision) and do not allow for a choice of appropriate distance correction, which results in reduced length of distance vision (75).

Contact lens wearers represent a group of people at higher risk for CVS symptoms. It is essential that even smaller amounts of cylinder (up to 0,75D) be corrected, especially if the patient finds toric correction more comforting during the subjective exam (50). Since single vision contact lenses are generally prescribed to young patients, a small amount of plus lens should be considered in presence of symptomatic patients. However, under-correction of myopic children and young adults could result in a greater degree of myopic progression, so the plus lens addition should always come in the form of single vision glasses meant exclusively for computer or other digital device use (76).

Patients with accommodative dysfunction must be treated in order to improve the accuracy and dynamics of the accommodative response. In case of

accommodative insufficiency, ill-sustained accommodation and accommodative infacility visual training is considered as an appropriate solution. The main goal of visual training for accommodative anomalies is to increase the amplitude, speed, accuracy and ease of the accommodative response (5). In case of accommodative infacility and spasm of accommodation, treatment with plus lenses must be considered initially, even though different authors mention that accommodation can be modified with training and that accommodative testing has been shown to improve accommodative response (77, 8). If the patient is not able to follow the visual training exercises regularly, plus lenses are often effective in reducing symptoms in patients with accommodative insufficiency (5). The methods that help determine the amount of plus lens power balance the positive and negative relative accommodation, the calculation of the AC/A ratio, near point retinoscopy and cross cylinder (5).

The therapy for patients with accommodative dysfunction generally consists of three phases. In the first phase, practitioners mostly use bigger targets to slowly change convergence in divergence demand, in order to increase vergence amplitudes (5). A spherical flipper (normally with a ± 1.50 D) is a must-have in every examination room where accommodative facility exercises are performed. In the second phase the aim is to fasten the response to accommodative stimuli. The minimization of the targets is required along with the patient's repetition of the tasks. Once the amplitudes reach normal levels, the power of the binocular accommodative flipper can be increased, until the patient can successfully clear ± 2.50 D (59). In the final phase large jump accommodative and vergence movements are required. The techniques that stimulate the accommodation while holding the vergence stable (and vice versa) help integrate accommodation and automate both accommodative and vergence response (5). Finally, the patient will have the ability of effortless accommodative response under any stimulus condition.

The accommodative system is, along with the vergence system, most important for a person's long-term visual comfort (79). It is recommended that most of the exercises are done in the presence of an eye practitioner. If this is not possible, home computerized therapy is also available and must be offered as an alternative, along with regular checkups (11).

Even though accommodative and vergence anomalies can be very similar and are often complementary, the two conditions should be approached differently. There are two general goals for treating vergence dysfunction in a CVS patient:

- To alleviate ocular, physical and psychological symptoms associated with vergence disorders.
- To help the patient achieve better visual performance in school, at work and in everyday life.

There are different methods available to manage vergence anomalies. The treatment of those anomalies is designed to reduce symptoms such as headache, asthenopia, poor visual performance at work or school, ocular fatigue and loss of concentration. Treatment methods are divided into the following categories:

- Optical correction.
- Visual therapy.
- Medical treatment.
- Surgery

Optical correction includes ophthalmic lenses and prisms. Ophthalmic correction is normally the first consideration in treating vergence anomalies. Plus lenses are affective in eliminating symptoms and can positively affect abnormal esophorias according to the AC/A ratio (5). Moreover, plus additions at short distances (determined by balancing the PRA and NRA values, cross-cylinder, near point retinoscopy and the calculation of the AC/A ratio) are often well accepted by patients with an abnormally high AC/A ratio, in case of convergence excess, or by patients with abnormally high near esophoric deviation. If a significant motor deviation is present, prism correction should be used (5).

Visual therapy is a method that has been shown to increase visual performance of patients with vergence anomalies such as convergence insufficiency; with different exercises it is possible to improve the near point of convergence and fusional convergence and to alleviate the symptoms (5). In order to achieve the best results, three phases must be accomplished: normalizing accommodative and vergence amplitudes, increasing the response speed of accommodative and vergence stimuli and finally achieving the ability to make large-jump

accommodative and vergence movements (5). Visual therapy is successful only when the improvement of both accommodative and vergence adaptation systems is achieved.

Both medical (pharmaceutical) treatment and surgery are rare. Extraocular muscle surgery is considered rarely, only when optical correction or visual therapies have not been well accepted by the patient and a significant heterophoria continues to produce symptoms (5).

5.2 DRY EYE MANAGEMENT

Dry eye has often been mentioned as one of the major contributors to Computer Vision Syndrome. Shadid et al (52) have found that decreased tear film break up time is a frequent cause of ocular discomfort in CVS sufferers. In another study, Uchino et al (80) have found a prevalence of dry eye in VDT workers of 10.1 % among men and 21.5 % among women. Moreover, the high prevalence of dry eye has been correlated with the time spent behind digital screens; the group which spent more time working with VDTs showed higher prevalence of dry eye (81).

It has been suggested that the following factors could induce ocular surface related symptoms:

- Reduced blink rate.
- Incomplete blinks.
- Increased corneal exposure.
- Contact lens wearing.

Reduced blink rate seems to be the most common factor that induces the symptoms of dry eye. Blinking has often been dealt with; in various studies researchers compared the rate of blinking and found that mean rates while relaxed were significantly higher than during a VDT use (82). In addition, Patel et al (83) have noted an important correlation between the precorneal tear film stability and the interval between blinks. Reduced contrast and font size plays a big role in dry eye (84). Worse image quality and a smaller electronic text may require more task concentration, which affects blink rate.

Incomplete blinking is an additional factor to consider when facing dry eye symptoms. Chu et al (85) have noted that a group with subjects following a reading task on a VDT had a higher prevalence of incomplete blinks and a higher total symptom score. Discomfort is a result of thinner tear film in the inferior part of the cornea, which tends to be more sensitive to instability (86). It has been suggested that the main risk factors for incomplete blinking are post laser refractive surgery and contact lens wear (87).

Since desktop computers are commonly placed at the level of the eye's primary position, there is a bigger corneal exposure than during the reading of a printed text, normally read with eyes depressed.

There are different diagnostic methods that can be performed in order to determine if the patient has dry eye. A slit lamp, being one of the most indispensable accessories in every eye care clinic, is used to examine the anterior and posterior segments of the eye. When inspecting dry eye, it is used to examine the cornea, the sclera and the conjunctiva. In addition, fluorescein sodium, rose bengal and lissamine green can be inserted into the patient's eye in order to stain the ocular surface. Fluorescein sodium is a nontoxic water soluble dye that is a tool useful in evaluating corneal epithelial defects, together with blue light (88). The induced staining shows corneal superficial punctuate epithelial erosions; for example low located erosions, at the bottom part of the cornea, could signify infrequent or inadequate blinking (88). A small amount of fluorescein sodium is also instilled during tear meniscus evaluation; measurements of the tear meniscus height (in normal conditions higher than 0.2 mm (89)) and curvature are essential during dry eye evaluation. Rose Bengal is a bright red stain which penetrates epithelial cells and attaches to those that are no longer covered in mucin (90). However, due to its toxicity to the corneal epithelium cells and the discomfort upon instillation, it is less frequently used than fluorescein (91). Rose bengal and green lissamine have similar staining patterns and can be used correspondently. Green lissamine is normally used to grade conjunctival staining (92).

Other tests that are useful in dry eye evaluation are: the Schirmer test (the most common invasive test used to measure tear production), tear osmolarity

evaluation, Meibomian and Lacrimal Gland evaluation and functional visual acuity (93).

5.3 BLUE LIGHT HAZARD

It is clearly understood that light, other than being beneficial, can be also harmful; dramatic increase in blue light exposure (the blue light portion from daylight is between 25 % and 30 % (94)) due to the overuse of various smart devices could result in damaged retinal cells (20). Thanks to numerous companies that invest a significant amount of money in the improvement of the care that optometrists are able to deliver, there are several products on the market offering high quality solutions to even the most complicated cases. The constant increase in prevalence of blue light related diseases entirely justifies strong primary prevention solutions to combat those conditions. Among those are specially designed eyeglass lenses that are based on the results of many conclusive studies concerning blue-violet light radiation toxicity, which can, theoretically, reduce photo toxicity by 10.6 % and up to 23.6 % without having a negative impact on visual performance (95). These lenses are covered with a blue filtering coating that modestly filters high energy and short-wavelength light. In addition, wearers also claim that lenses with a blue filtering coating provide better anti glare performance and, having a lower wavelength and being focused before the retina, do not reduce visual performance during near computer or other smart devices work (95).

In addition to the blue filtering coating, melanin also plays a huge role in blue light protection. Putting melanin in lens is one of the first evolutions used in order to protect the eyes from damaging light. Melanin is a natural pigment that is best known for its presence in the human skin, hair and eyes. Since melanin is capable of absorbing a wide range of blue light, both good and harmful, it has been highly recommended as an optical solution to reducing blue light (20).

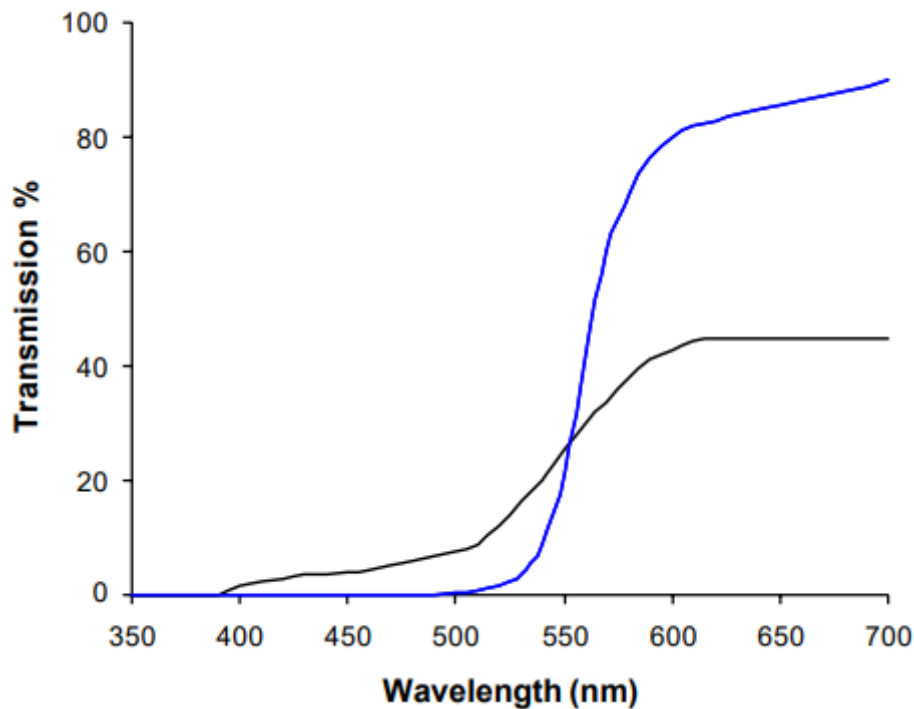


Image 4: Transmission characteristics of yellow/orange filtered lens (in blue) and bronze lens (in black) that reduce the amount of harmful blue light reaching the retina, from 415 to 455 nm (96).

5.4 ERGONOMICS: COMPUTER WORKSTATION POSITIONING AND MOBILE DEVICE USE

Though often neglected, the viewing of the computer is one of the most important factors that induce Computer Vision Syndrome. Extended use of digital screens may lead to discomfort such as experiencing pain as a result of poor posture, improper adjustment or use of workstation components or other factors. A poorly designed workstation might not only have short-term effects, but can also affect workers health and productivity. On the other hand, correctly managed and arranged workstation could play an important role in increasing work productivity and the patient's comfort. In order to reduce discomfort and other symptoms, the patient must always be taught about the arrangement of the work environment and equipment. To provide the optimal conditions for office workers, the Italian government in 2008 introduced a decree 81/08, which ensures a safe workplace and protects office workers of work stress induced by different factors, including prolonged video display terminal use. Among various attachments of the decree

81/01, the number XXXIV describes minimum requirements for an appropriate workplace, including (106):

- Work area.
- Desk or workstation.
- Chair.
- Monitor, keyboard and mouse.
- Lightning.
- Work habits.
- Laptop computer.

The work area is a place where the patient works, such as an office or even their desk at home. It should be spacious enough to allow the full range of motions involved in performing required tasks, in order to provide enough space for equipment materials and to present the patient with a comfortable work area.

The work surface is one of the essential factors in preventing musculoskeletal disorders of the upper body. A too high desk will increase the risk of fatigue and discomfort, forcing the patient to raise arms and shoulders in an unnatural position held for an extended amount of time (97). Similarly, a too low desk will force the patient to lean forward, placing stress on the arms and shoulders, which can even lead to a decreased viewing distance. The recommended workstation height is between 70 and 80 cm; the patient must have enough space to comfortably move both upper and lower parts of the body and must permit the entrance of the chair under the desk (98). Additionally, the desk must be appropriately stable, with a low refractive index, and big enough for the monitor, keyboard, mouse, documents and other accessory material (98). The chair represents the most adjustable component of all workstation equipment. When modifying the chair, some characteristics must be taken in consideration, such as the height, backrest angle and weight, seat pan angle and armrest weight. The right position of the feet is flat on the floor, with knees at a 90° angle so as to avoid excessive pressure on the back. The thigh-to-trunk angle should also be around 90° with the back being pushed to the chair in order to fit the spinal contour. With the backrest angle arranged properly, both arms should also be positioned parallel to the floor and the wrist should be in a neutral, almost straight position. Only in this case are the

arms relaxed and using the work surface for support, in order to reduce the static load on the muscles.

Once the chair and the desk positions have been established, the digital screen should be positioned. The most important criteria that must be considered are distance, height and the inclination of the computer monitor, which are highly correlated with visual discomfort. The distance between the digital screen and the eyes is one of the most crucial factors that can either worsen or improve the patient's visual and postural discomfort. The appropriate distance is usually determined according to the size of the digital screen, the characters and the adjustability of the workstation. Generally, the most appropriate distance is between 50 cm and 70 cm (14). The height of the screen should also be considered, as accommodative amplitude reduces with the elevation of the eyes (99). The recommended height of the top of the screen of 18 cm below the horizontal level of the eyes (about 20 degrees) decreases the risk of dry eye, spasm and neck pain and also reduces the stress on the eye muscles (19).

Lightning is a significant environmental factor affecting the patient's visual performance. A poorly illuminated workplace can lead to eye strain, fatigue and stress, while too much lightning inducing glare can also negatively affect the worker's productivity. The International labour office in Geneva has indicated that improved lightning resulted in a 10 % increase in productivity and a 30 % reduction in errors (100). Windows, desk lights and fluorescent lights positioned above the head often contribute to discomfort and if not controlled by a properly arranged workstation can induce reflections and glare, which are one of the causes for migraine related symptoms (101). Additionally, screen reflections, producing a veil of light over the digital screen, reduce contrast and visibility (14). There are various filters that can be used to reduce glare and reflections. However, those filters should be always recommended as supplements and do not replace proper lightning design and workstation positioning. The lightning of the surrounding room should also be balanced. Generally, 200-500 lux is recommended, with lower levels of lightning for dark background screens and higher levels (over 500 lux) needed in case of poor quality documents (14).

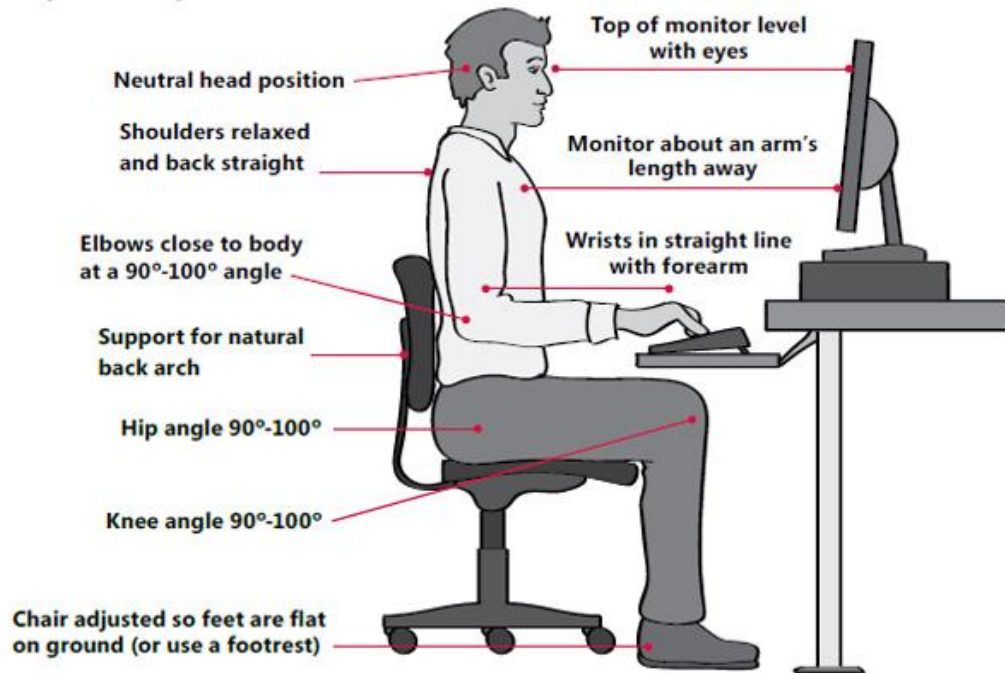


Image 5: Proper workstation positioning (102). It is suggested to avoid abnormal body positions and to maintain correct posture in order to improve comfort and productivity.

As mobile devices are being preferred by younger generations, maintaining correct posture might present a big challenge to some of the children. The overuse of such technology, in conjunction with poor ergonomics, generally causes a number of musculoskeletal problems, such as neck and back pain. As the smaller devices, containing smaller digital characters, are usually held closer to the eyes with the head tilted forwards, greater force is put on the cervical spine. To avoid postural discomfort, it is necessary to instruct the patient about proper ergonomics, such as holding the device at eye level or in alternative positions, such as lying on the back with the knees bent and the feet flat on the floor, or even using voice instead of texting.

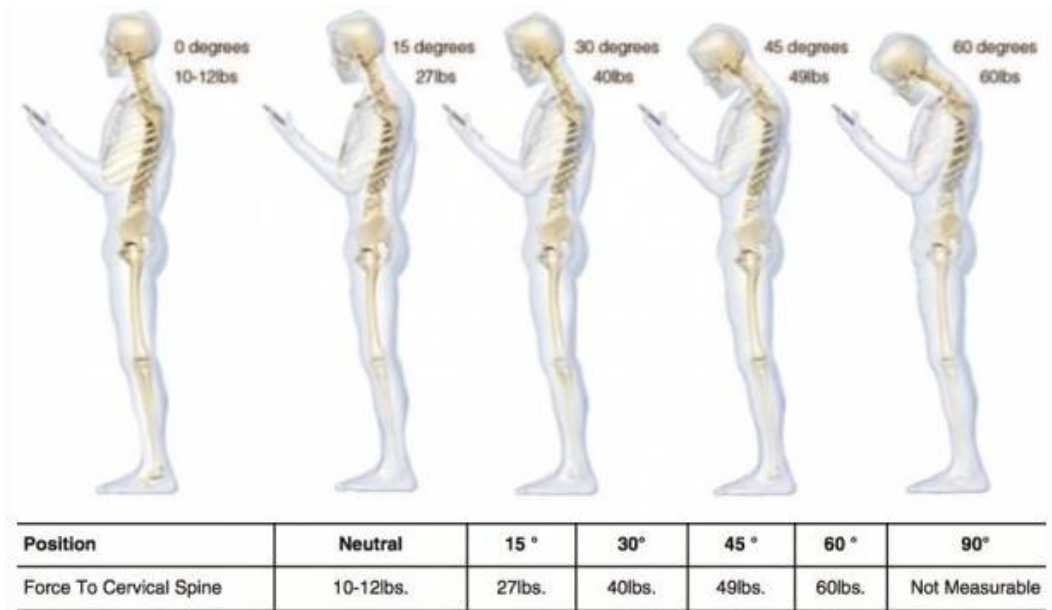


Image 6: An angle of 60 degrees could be compared to a 27 kg load on the cervical spine, which is five times higher than when holding a smart device in the natural position (103).

VI. CONCLUSION

Computer Vision Syndrome is one of the most threatening occupational ocular health hazards of the 21st century. As the number of computer and smart device users grows every year, the prevalence of the eye strain is likely to increase over the next years. Despite its harmful and aggravating consequences, various current studies explore the digital world and the most common symptoms and propose many solutions that eye care professionals should consider in their offices. Considering the actual situation, most optometrists find a solution in proper workstation positioning and the correct addition for near work.

Younger generations present the biggest risk of developing not just Computer Vision Syndrome, but also a rapid myopic progression, which has been noted in the south-east part of Asia. Moreover, social life is being transferred to digital devices, where numerous social media are changing the way of communication and increasing the time spent online. As mentioned already, many children own a digital device from the early childhood and are not taught to avoid the temptation of constant use. The ever-growing behaviour of digital device use should be concerning, as it could have a long-term impact on the well-being, both social and physical, of the younger generations.

Finally, the main objective of all eye care professionals is to ensure comfortable vision. Vision problems associated with the prolonged use of digital devices, being one of the most prevailing health threats, should be considered more often when it comes to a patient with CVS symptoms. Prevention, including a proper ergonomic environment, education and frequent visual examinations, are the main strategy for the management of CVS. When prevention is no longer an option, there are different ways to alleviate the symptoms. The key to successfully combat the problems correlated with the over-use of digital screens is to intervene early. There are different types of methods to partially or completely eliminate the patient's visual discomfort, thanks to the organisations that encourage eye care professionals to fight hazardous complications of digital device use. The biggest med-tech companies support optometrists all over the world and by market

extension offer various solutions to combat the symptoms of prolonged digital device use. Apart from coloured filters, innovators and developers are forming new types of multifocal lenses, made for computer and other digital screen use, with wider intermediate corridors, that offer patients even more comfortable intermediate vision at work and at home. However, the rapidly digitized world is, undoubtedly, modifying people's behaviour, starting from the quality of vision and posture and consequently, the visual demands required for operating modern technology will continue to increase. The ability to satisfy the visual requirements of patients suffering from vision problems correlated to the prolonged use of digital devices, would in part decrease the number of affected users and increase the quality of the service that optometrists are able to offer to the patients.

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